

An Innovative Network to Improve Sea Ice Prediction in a Changing Arctic

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LONG-TERM GOALS

The overarching goal of this project is to understand sea ice predictability and improve sea ice predictions system by defining key observations, improve technical approaches for prediction, and refine communication of predictions.

OBJECTIVES

To achieve our goals, we have established a collaborative network of scientists and stakeholders known as the Sea Ice Prediction Network (SIPN). The SIPN leadership team extends beyond the University of Washington component, and the team receives multi-agency sponsorship. The University of Washington team, funded by ONR, is focused on the following three objectives:

- (1) Coordinate and evaluate predictions: The SIPN team organizes the Sea Ice Outlook (SIO) each summer. A core group of dynamical and statistical modelers in SIPN is exploring the limits of Arctic sea ice predictability over seasonal-to-interannual time scales. We lead the design of SIO and additional experiments to intercompare predictions with common methods. We will also develop strategies for predictability studies that isolate the role of uncertainty in initial conditions and inherent model predictability and develop skill metrics tailored to evaluate sea ice predictions. At the same time, we will work with our SIPN collaborators to identify and evaluate the types of data that bring about measurable improvements in model performance and predictive skill and serve as the initial conditions for predictions. This effort will provide guidance on observing system needs and a synthesis of predictive skill assessments from different approaches for high-priority variables. A final objective of our group is to identify model deficiencies and work with model developers to improve models for prediction.
- (2) Synthesize predictions and observations: We will review summer monthly sea ice evolution, open water sea surface temperature (SST) fields, and atmospheric forcing (wind and radiation) to synthesize findings and include modeling to place recent sea ice change into system-wide context. We will use models and observations to ask whether “2007–2012 is the New Normal” or “was natural variability responsible in part for rapid loss from 2007-2012, and moderated loss is more probable now”. Through comparisons of the observed sea ice evolution and relevant processes with previous SIO predictions, the strengths and weaknesses of different prediction

approaches will be evaluated. At the same time we will explore how methods can be combined to improve understanding and forecasts.

- (3) Disseminate predictions: We are improving the content, format and delivery of products from the SIO to address information and research needs of key stakeholders (including federal and state agencies) and build a more informed public. We are requesting that SIO contributors provide more specific regional forecasts, more accessible meta-analysis, and information to compare research approaches.

APPROACH

We continued our effort to build and maintain the SIPN community of scientists and stakeholders this year through our web site, AGU team meeting, webinars, monthly call to participate in the SIO and synthesis reports in summer, and in numerous presentations at conferences and symposia. We wrote a number of peer-reviewed journal articles about the SIO and results from the SIO. Cecilia Bitz and Edward Blanchard-Wrigglesworth continued to spearhead the gathering and analysis of forecasts at the local-scale. Blanchard-Wrigglesworth and Muyin Wang worked together designed a second SIPN experiment, with participation from 6 forecasting centers. Wang and James Overland are also doing a detailed evaluation of the CFSv2 operational forecasts (2012-2015) to better understand the characteristics of that forecast system's atmosphere and sea ice conditions.

We joined SIPN leadership team telecons approximately once per month. The leadership team together plans each SIO call for contributions, with the intention of enhancing the scientific content of the SIO, by developing and refining a questionnaire template.

In April 2015, Bitz, Wang, and Blanchard-Wrigglesworth attended a SIPN second annual "workshop on Polar Predictability" held at Reading, UK. During the workshop our UW team members gave oral presentations, chaired session, and actively participated in the discussions. We received additional feedback for the SIO.

Wang contacted modeling institutions in China (IAP, BCC, FIO, and Tsinghua University) again this year to invite their participations in the SIO activities. She assisted FIO with their submission at the beginning the season, and then FIO submitted on their own in the latter two months. Reaction from the other teams in China are positive, but they require more time before they can participate. Wang will continue to work with those modelling groups in the coming year.

Another way we expand the reach of SIPN is through our contributions to other organized groups. Bitz and James Overland frequently participate in the IARPC Sea Ice Working Group. Wang was selected to serve on two USCLIVAR panels; Predictability, Prediction, and Applications Interface (PPAI) and Arctic-Midlatitude Working Group; this year. Overland is also a member of the Arctic-Midlatitude Working Group. Blanchard-Wrigglesworth is on the American Meteorological Society Polar Committee. Bitz co-leads the WCRP Polar Climate Predictability Initiative. Bitz also served on an NRC study group on Subseasonal to Seasonal Prediction, resulting in a report that is presently under review.

WORK COMPLETED

The UW team contributed to the preparation of the three calls for SIO contributions, analyzing the SIO contributions, and writing the SIO summary reports in June, July, and August 2015. The SIO summaries contain a nowcast of sea ice conditions and our analysis of the SIO contributions. These reports are published on the SIPN web site.

Blanchard-Wrigglesworth and Bitz published the results of the SIPN forecast intercomparison that we initiated in a webinar in February 2014. Four forecast centers participated by testing the sensitivity of a 2013 September forecast using May initial conditions to a 1 m perturbation in the initial conditions. We described the results in our 2014 Annual Report. The work is now published in Blanchard-Wrigglesworth et al, (2015, see publications list).

Members of the UW team lead a second annual 2015 intercomparison forecast of the SIPN. This effort involved Wang coordinating with Jinlun Zhang to obtain the PIOMAS ice thickness distribution data as soon as it became available in spring. Blanchard-Wrigglesworth then regridded the data to be compatible with the CICE model, which is used by a number of our participants. The data were distributed and throughout summer results have been sent back to Blanchard-Wrigglesworth. Our analysis is underway.

Blanchard-Wrigglesworth provided analysis of the local-scale 2014 SIO data to a summary journal article about the 2014 SIO written in collaboration with a SIPN science team lead by Julienne Stroeve (Stroeve et al, 2014). Blanchard-Wrigglesworth also collaborated with a team lead by Demetris Dukhovskoy to use the local-scale 2014 SIO dataset as test cases to demonstrate a number of new metrics for evaluating the sea ice “edge” as a contour in space. Blanchard-Wrigglesworth co-authored a journal article with the group (Dikhovskoy et al, 2015). Our analysis of the local-scale 2015 SIO data is underway.

Wang organized SIPN’s four, bi-monthly webinars this year. The responses to our webinars are very positive: we had 89 people register for our March webinar (given by E. Hunke), 115 for May webinar (given by N. Kurtz), 107 for August webinar (given by A. Tivy and H. Eicken), and 79 for October webinar (given by J. Stroeve, L. Hamilton, and C. Bitz).

As of now, Wang and Overland have collected NCEP operational CFSv2 forecast products for the past 4 years (January 2012 to September 2015). The initial analysis showed that summer, especially September, has the lowest predictability in the operational products, which is different from the CFSv2 retrospective forecast results (Wang et al. 2013). We will further analyze the atmospheric forcing fields in order to identify which fields contributed most uncertainty and what is potential way to improve this.

RESULTS

We have collected and analyzed a pair of local-scale fields from the SIO in 2014 and 2015. The first field, the September Sea Ice Probability (SIP), is computed by first converting the sea ice concentration from a single ensemble forecast into an ice present field (1 if the concentration is above 15% and zero otherwise). SIP is then the ensemble mean of the ice present field across an ensemble of forecasts. The second field is the first Ice-Free Day (IFD) of the year, presented as a Julian day. Figures 1-4 show results from these two new fields.

We have used a number of skill metrics to quantify the local-scale fields. SIP from the five contributions we received in 2014 is shown in Figure 1. Using a Brier skill score as a metric of the spatial average of the local-scale bias we find two important results: (1) The multi-model mean has higher skill than any individual forecast, and (2) The forecasts made at shorter lead time are more skillful. Extrapolation is used as a baseline, upon which a forecast must improve upon in order to be considered skillful. Only the multimodel mean and two of the forecasts with shorter lead times are skillful compared to extrapolation.

The sea ice edge derived from SIP from the same forecasts in Figure 1 were analyzed using five new skill metrics based on topology (Dukhovskoy et al, 2015). The new metrics yield significant differences in the evaluation of skill. The authors concluded that the metric based on a Modified Hausdorff Distance (labeled MHD in Figure 2) approach is the most robust. The MHD metric is in qualitative agreement with the Brier skill scores as well.

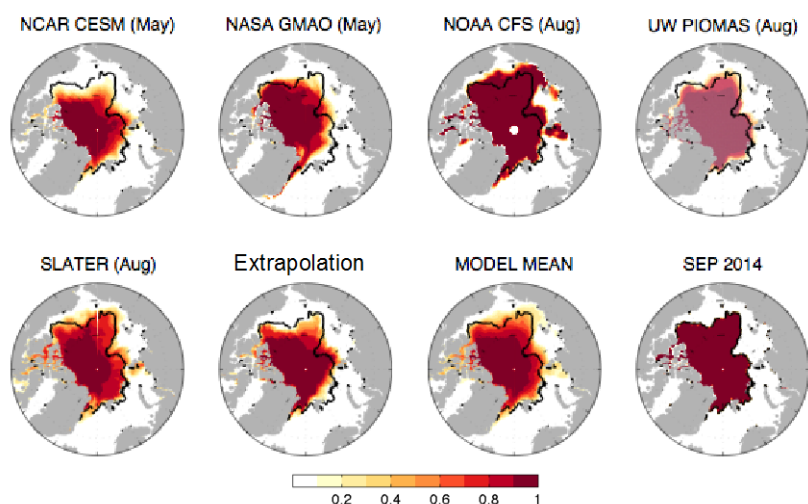


Figure 1: September Sea ice probability (SIP) from five contributions to the 2014 SIO with forecast issue date as shown. Extrapolation of the observed 1979-2013 passive microwave data is shown as a baseline estimate. A SIP of 0.5 is comparable to the sea ice extent (15% concentration contour) shown as a black line in each panel from observations in 2014. All contributions in the top row are ensemble means of individual forecast systems. SLATER is a stastical forecast.

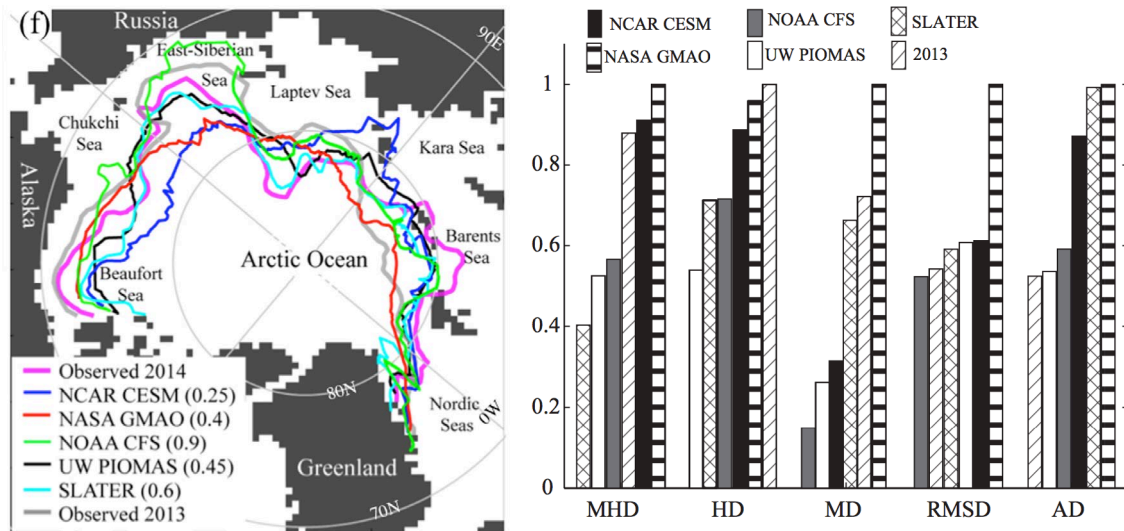


Figure 2: Analysis of the September sea ice edge taken from the 0.5 contour of SIP from 2014 from the contributions presented in Figure 1. The left panel illustrates the edge in the forecasts and observed in 2013 and 2014 (from the 15% concentration contour). The right panel indicates the skill score of the edge in the forecasts using the five metrics (MHD, HD, etc) developed by Dukhovskoy et al (2015). The edge in year 2013 (persistence forecast) is compared to 2014 as a baseline of skill. For each metric, the most accurate prediction is the furthest left, and all metrics are normalized for comparison. Only those left of the skill metric for 2013 have outperformed a persistence forecast.

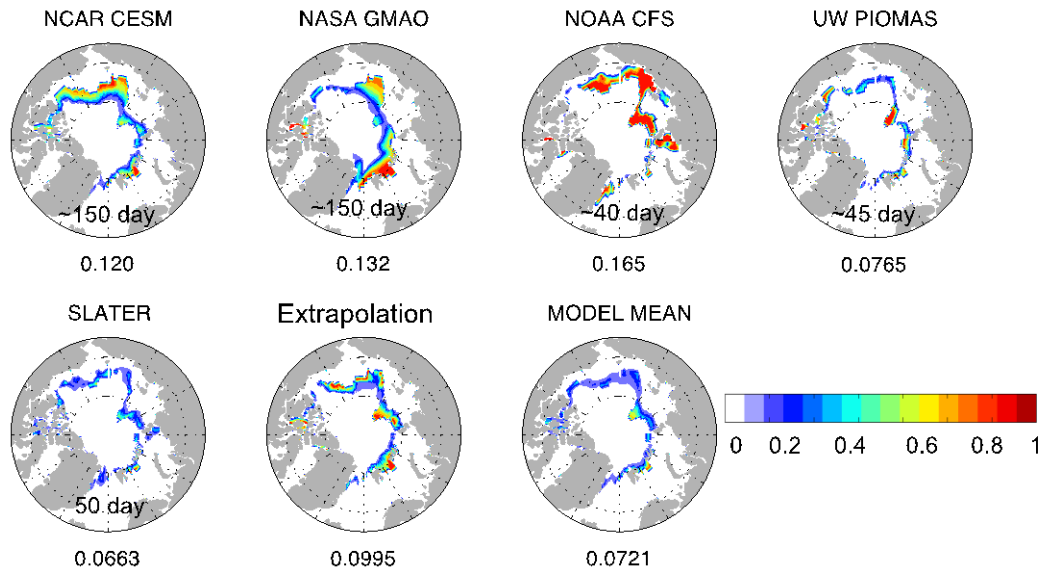


Figure 3: Brier skill metric applied to first Ice-Free Day (IFD) from the 2014 SIO at the local scale (in color) and total for the Arctic Basin (number under each panel). Zero (white) is a perfect forecast and one (red) is forecast with no skill. The approximate forecast lead times are indicated on each panel. The multi-model mean and the UW PIOMAS and SLATER forecasts are skillful compared to extrapolation.

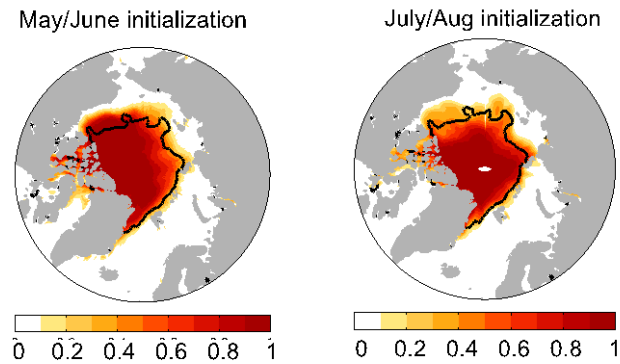


Figure 4: September Sea ice probability (SIP) in the 2015 SIO from five contributions in the early season (left) and four contributions in the late season (right). A SIP of 0.5 is comparable to the sea ice extent (15% concentration contour) shown as a black line in each panel from observations in 2015.

The value of these local-scale fields is further exemplified by the fact that the skill metrics that seem most robust indicate a very different relative skill among the forecasts compared to the bias of the pan-Arctic forecast of sea ice extent. Thus the utility of a forecast is probably not well represented by the success at predicting pan-Arctic extent.

Our analysis of IFD from the 2014 SIO (Figure 3) confirms the same two conclusions from analyzing SIP with regard to skill being higher in the multi-model and generally at shorter lead times. Our analysis of the 2014 SIO is more extensive since we have had more time since the data were collected. However, the opportunity for analysis is even greater now because more groups contributed data in 2015. Here we include only a brief compare SIP in Figure 4 for the early and late submissions in 2015. The later forecasts are improved throughout most of the area along the ice edge from the Beaufort to the Laptev seas. Further analysis of the 2014 and 2015 local-scale fields will be forthcoming in a paper that is in preparation.

In our analysis of the CFSv2 sea ice forecasts, by comparing sea ice extent with the Hadley sea ice analysis (HadISST_ice), we found that the largest forecast error lies in September at 2 and 5-7 month lead times. In the summer and early fall (July – Oct), the CFSv2 forecasts are too extensive (positive bias), while in the rest of the year they are not extensive enough (negative bias, see bottom panel in Figure 5). However, in the retrospective forecasts, shown in the top panel of Figure 5, the CFSv2 has a positive bias most of the year (January to September), but a negative bias in the early fall (October to December), during the ice growing season. This illustrates the challenge the real time operational forecasts face: even with the same model, the retrospective and “future” forecast results can be different. Analysis is underway to explain the difference.

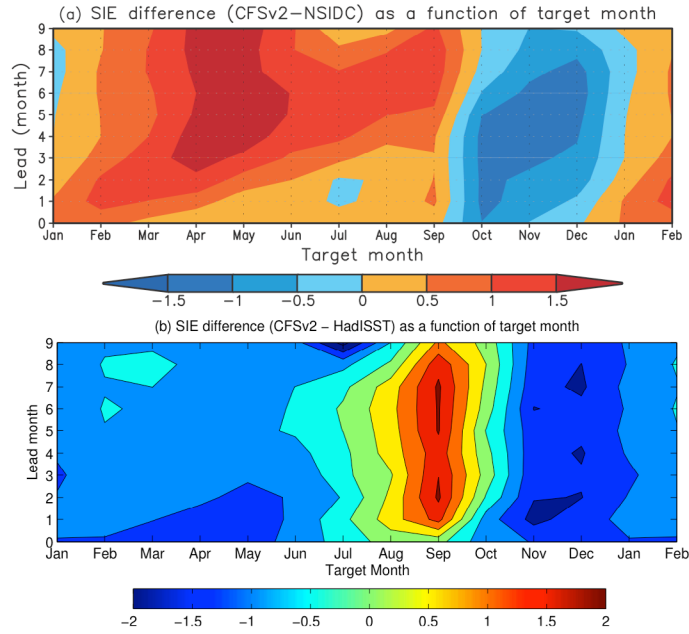


Figure 5 Sea Ice extent forecast bias compared with observations based on CFSv2 for (a) hindcasts for 1981- 2010 and (b) operational forecasts (2012-2014). Units are in millions square kilometers.

We further investigated the detailed structures of the sea ice property in CFSv2. What we found is that the CFSv2 forecasts overall underestimate sea ice concentrations (Figure 6), and the summer positive bias with 2-month lead forecast time in the sea ice extent is most likely due to the too much thick ice, which is shown in the domain averaged thickness bias at lead times of 0-2 month in Figure 7. Except for short periods in summer, the CFSv2 has systematic ice thicknesses biased toward thinner ice when the forecast lead time longer than 4 month. Whether these biases are due to the ice model component in the CFSv2 or due to the atmospheric or oceanic coupling fields is currently under investigation.

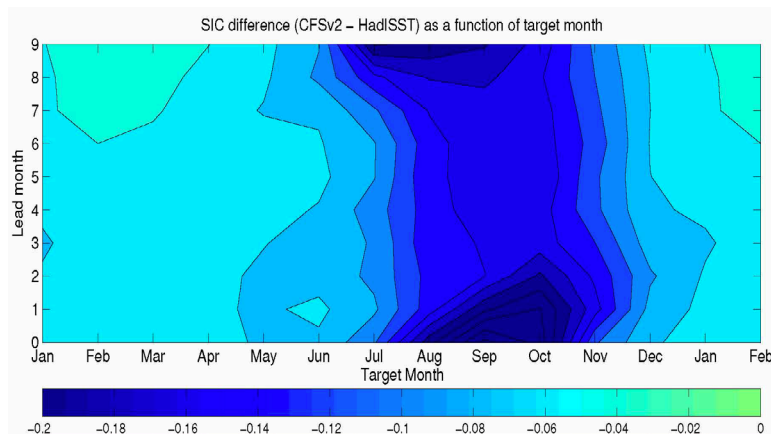


Figure 6 Prediction bias in domain averaged sea ice concentration (70-90N) as a function of forecast leading time (in month). Units are percentage (%).

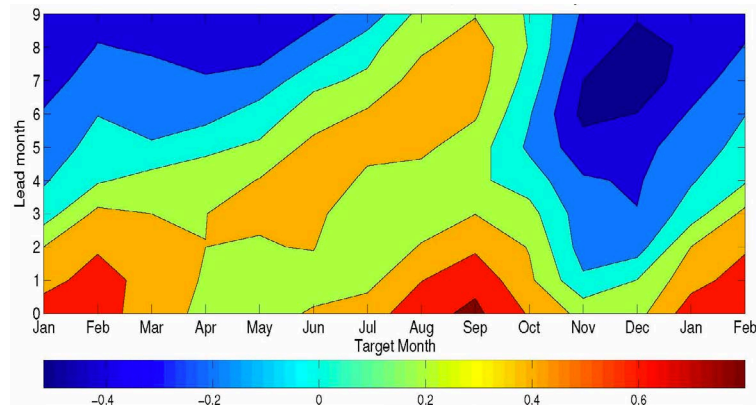


Figure 7 Prediction bias in domain (70-90N) averaged sea ice thickness compared with that assimilated in PIOMAS. Results are based on 2012-2014 averages. Units are in meter.

IMPACT/APPLICATIONS

Loss of sea ice in recent decades has opened the Arctic Ocean to increasing access of wide-ranging vessels and activities. The Navy is concerned about the potential for conflict and need for search and rescue on the Arctic Ocean. Each year the sea ice cover is different owing to natural variability and forced change. Forecasts of Arctic sea ice and atmospheric conditions have high societal value if they predict when ship transit lanes will be open and where low ice cover might lead to dangerous coastal erosion or ice shelf break-up. Sea ice forecasts have scientific value as they could inform scientists of locations that should be instrumented to monitor large anomalies. This project aims to improve Arctic sea ice prediction of the natural variability and forced change, which is a benefit to society, scientists, and Naval operations. We also seek to improve sea ice models in general.

RELATED PROJECTS

ONR project N00014-13-0792 Early Student Support to Investigate the Role of Sea Ice-Albedo Feedback in Sea Ice Predictions is also about understanding sea ice predictability.

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HONORS/AWARDS/PRIZES

Cecilia Bitz of University of Washington in 2015 was elected a member of the Washington State Academy of Sciences.

Cecilia Bitz of University of Washington in 2015 was listed on the Highly Cited Researchers of 2015 by Thomson Reuters.